A. 11.

HEART IRREGULARITIES, RESULTING FROM THE INHALATION OF LOW PERCENTAGES OF CHLOROFORM VAPOUR, AND THEIR RELATIONSHIP TO VENTRICULAR FIBRILLATION.

By A. GOODMAN LEVY and THOMAS LEWIS.

Reprinted from "Heart."
Vol. III, No. 1, October 30, 1911.

WELLCOME INSTITUTE LIBRARY
Coll. welMOmec
Coll. pam
No. WG 200
1911
L67h

[*Reprinted from "Heart."*
Vol. III, No. 1, October 30, 1911.]

HEART IRREGULARITIES, RESULTING FROM THE INHALATION OF LOW PERCENTAGES OF CHLOROFORM VAPOUR, AND THEIR RELATIONSHIP TO VENTRICULAR FIBRILLATION.

By A. GOODMAN LEVY and THOMAS LEWIS.*

(*From University College Hospital Medical School*).

Introduction.

The following research was undertaken with a view to the further elucidation of certain cardiac phenomena, originally observed by one of us in connection with the administration of low percentages of chloroform to cats, and described in the form of a preliminary communication to the Physiological Society.[4] In this paper a peculiar form of blood pressure curve was described, which is characterised by rapid heart action, high or medium blood pressure, and certain fluctuations and irregularities which are made evident by reason of the inertia of the mercury column in the Ludwig's manometer. This peculiar form of curve was found to occur quite commonly under chloroform administered at a lower percentage strength than 1 per cent., or thereabouts ; and it is necessary to emphasise the point that it was obtained with great frequency in animals which had not had a large initial dose of the anæsthetic, and that it was not seen when the animals were under the full influence of the chloroform ; it may be added, in confirmation of its frequent incidence, that it was readily obtained in the five experiments which form the basis of the present paper.

The significance of this irregularity was deduced from its uniform appearance immediately before the occurrence of heart failure as a result of fibrillation of the ventricles, a condition which was shown to occur in certain isolated instances in the course of a series of experiments carried out in another investigation upon cats under the influence of chloroform. Certain other irregularities, characterised by a regular intermission of the heart beat, were also frequently observed and appeared to be conditioned by the administration of a somewhat less rarified proportion of vapour.

It was further demonstrated that fibrillation of the ventricles could be induced in a large proportion of cases by the intravenous injection, under light chloroform anæsthesia, of small doses of adrenalin chloride, a drug which does not have a like effect under full chloroform anæsthesia or under any other ordinary experimental conditions ; and that, when the cardiac

---

* Working under the tenure of a Beit Memorial Research Fellowship.

tracing was regular in the period preceding the injection, it assumed a form of irregularity before the onset of fibrillation, which was apparently similar to that described above as occurring spontaneously.

These observations appeared to us of sufficient importance to call for an investigation which would reveal the precise nature of the several heart mechanisms present under light chloroform anæsthesia.

Method.

Cats were employed exclusively. They were anæsthetised with chloroform regulated in percentage terms by means of an apparatus already fully described by one of us.[5] A definite and known percentage of chloroform was conveyed by means of a Brodie's pump, through an elastic bag which served to convert the stream from an intermittent into a continuous one, to a funnel completely covering the face of the animal.

A blood pressure curve was taken on a kymograph drum, Hürthle's manometer being employed, with half saturated sodium sulphate solution in the connecting apparatus. Electrocardiographic curves were also obtained from time to time throughout the same experiments. The lead was in each instance from right shoulder to left groin. Two electromagnetic signals working in a single circuit (one writing upon the kymograph drum, the other upon the photographic paper) allowed simultaneous index marks to be recorded, and permitted the identification of the same beats in the Hürthle curve and electrocardiogram.

Intravenous injections of adrenalin chloride, as supplied by Parke, Davies & Co., were employed in the experiments. The dose administered was $\frac{1}{4}$ to 1 minim of the 1 in 1,000 commercial solution, (0·016 to 0·065 milligrammes), this being diluted with twenty times its bulk of normal saline solution previous to injection into the saphenous vein.

The irregularities produced by light chloroform anæsthia alone.

The sole reference which we have found to irregularities of the heart, of the forms we describe and in experiments on chloroform, is in a paper by McWilliam.[8] This writer incidentally mentions irregularities, which apparently correspond to the premature beats and bigeminal pulse which are fully discussed in the following paragraphs.

The irregularities of the heart, seen under light chloroform anæsthesia alone, were of varied form ; a number of these will be described, and the description will be simplified if the irregularities observed in a single and typical experiment receive detailed attention. Emphasis should nevertheless be laid upon the fact that, from experiment to experiment, the types of irregularity encountered were very constant in form. Irregularity of the heart occurred when the tension of chloroform vapour in the inspired air

varied between ·5 and 1·5 per cent. Repeated observation showed a definite relationship between the mechanism of the heart and the degree of anæsthesia. Thus, any animal which had inhaled 0·5 per cent. vapour for a few minutes, presented irregularity of the heart's action, and this was often marked in its degree. Similar irregularities were observed with higher percentages, for example 0·8 to 1 per cent., but as a general rule the degree of irregularity was less marked. Continued inhalation of percentages exceeding 1·5 per cent, usually abolished all irregularity. Short inhalations of 2 per cent. invariably abolished it.

The experiment chosen to exemplify the effects of chloroform upon the undamaged heart is illustrated by the electrocardiograms in Fig. 4. The animal was anæsthetised with 2 per cent. vapour, and during the succeeding ten minutes the strength was reduced in steps to 1 per cent.. The heart beat perfectly regularly on this percentage for five minutes, when the strength was reduced to 0·5 per cent.. A minute or so later the electrocardiogram and Hürthle curve showed marked irregularity. An electrocardiogram taken at this stage presented a tachycardia at the rate of 280 per minute and of the type seen in Fig. 4, *VI*; the actual curve is not published. The second electrocardiogram was taken approximately five minutes after the inhalation of 0·5 per cent. vapour commenced and is shown in Fig. 4, *I*. The curve demonstrates a regular bigeminy of the heart, due to premature contractions, such as are obtained on excitation of the apical or left portions of the ventricular musculature. The sequential beats are represented by the usual summits, *P*, *R* and *T*, and each cycle of this form is followed by an anomalous complex of which the first deviation is in the apex-negative, the second in the base-negative direction. The sequential auricular contraction, (*P*) to which there is no ventricular response, falls with the anomalous complex and is readily identified in the curve.

The animal was next placed upon 1 per cent. vapour and after five minutes had elapsed, Fig. 4, *II* was obtained. The curve shows the regular occurrence of a premature ventricular contraction after each second normal or sequential cycle. It is to be noted that the type of anomalous ventricular complex has changed, but that it is still complicated by the sequential *P* summit which falls at or near its commencement. Fig. 4, *III* was obtained some five to six minutes later and subsequent to the reduction of the strength of vapour to 0·5 per cent.. The simultaneous Hürthle curve is shown in Fig. 1, and the corresponding beats in the two curves are numbered. A bigeminy is present in that part of the tracing covered by the signal marks, and it is brought about by premature ventricular contractions. The normal cycles (*P*, *R* and *T*) are followed by anomalous complexes and these are alternately of the types seen in Fig. 4, *I* and *II*.

A few minutes elapsed and the percentage was changed to 0·8 per cent.; a little later the heart showed a trigeminy (Fig. 4, *IV*). Premature contractions are shown in this figure after each second normal cycle. The corresponding ventricular complexes are of a third type, and consist of first

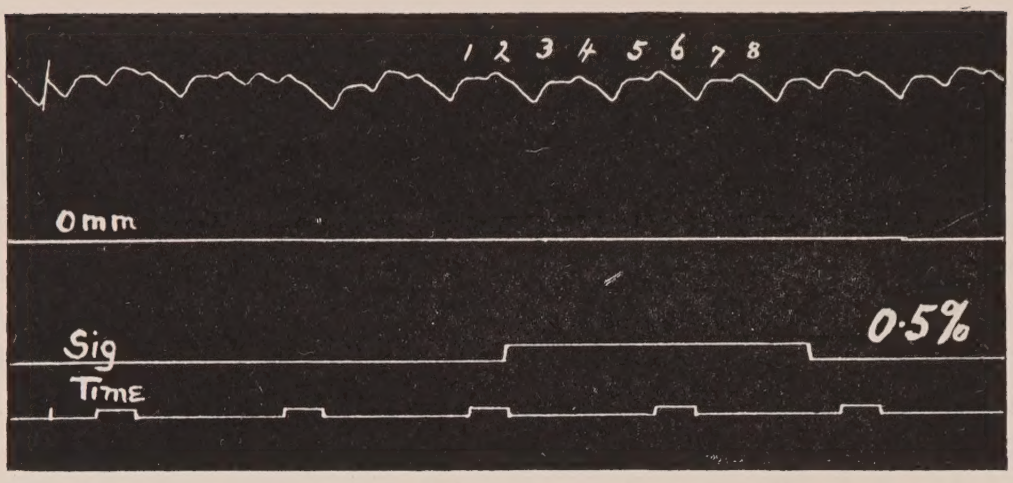

Fig. 1. A Hürthle manometer curve from the carotid of a cat under 0·5 per cent. chloroform vapour. The arterial curve shows an irregularity due to the presence of premature contractions. A portion of the curve, corresponding to the signal, has its beats numbered; the same beats are numbered in the simultaneous electrocardiogram shown in Fig. 4, *III*. The time is in 1·8 sec..

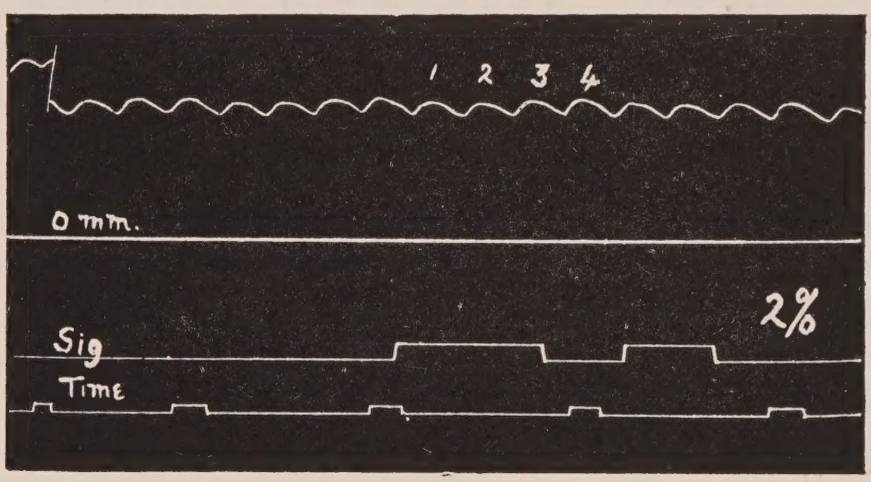

Fig. 2. A Hürthle manometer curve from the same animal, under 2 per cent. chloroform vapour The arterial pulse curve is regular; the blood pressure has fallen. A portion of the curve corresponding to the signal has its beats numbered; the same beats are numbered in the simultaneous electrocardiogram shown in Fig. 4, *V*. The time is in 1·8 sec..

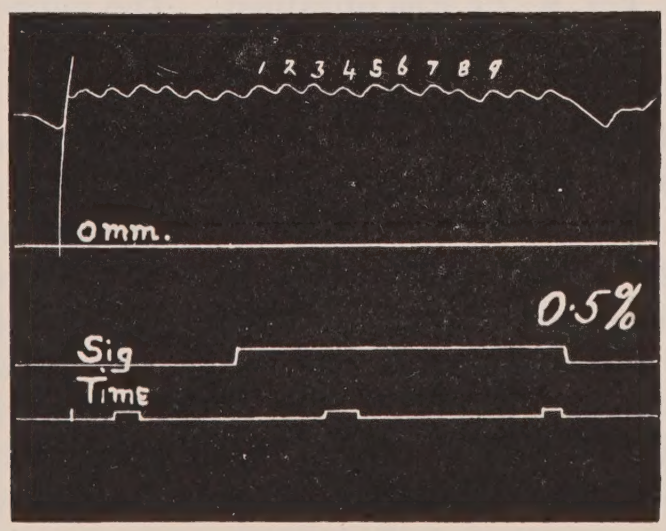

Fig. 3. A Hürthle manometer curve from the same animal, under 0·5 per cent. chloroform vapour. The arterial curve shows a number of rapid and almost regular beats, except towards the end where a pause occurs. Note the high blood pressure as compared to Fig. 2. A portion of the curve corresponding to the signal has its beats numbered; the same beats are numbered in the simultaneous electrocardiogram shown in Fig. 4, *VI*. The time is in 1·8 sec..

tall base-negative summits and secondly apex-negative summits; they conform in type to the anomalous complexes obtained upon stimulation of the basal or right portions of the ventricular musculature.

We need not concern ourselves with the accurate localisation of the origin of these beats; it is sufficient to emphasise the fact that each represents the origin of a ventricular contraction from a separate and fixed point or area, and that while in some curves the irregularity is due to new impulse formation from a single point or area (Fig. 4, *II*), in others two centres are active (Fig. 4, *III*).

The animal was placed upon 2 per cent. vapour and after the lapse of a few minutes the heart became perfectly and continuously regular. The mechanism is shown in Fig. 2 and 4, *V*, curves which were taken simultaneously. It is to be observed that the blood pressure had fallen somewhat with the rise in the percentage of vapour; the heart rate shown in the figure is 122 per minute. At the termination of this observation 0·5 per cent. was again administered and the simultaneous curves shown in Fig. 3 and 4, *VI* were obtained. The mechanism depicted in these figures, or a very similar mechanism, is extremely common upon the lighter percentages, and its analysis is aided by comparison with the other curves taken from the same animals. It consists of a rapid tachycardia of ventricular origin and is composed of beats which are placed at approximately regular intervals. The point of origin of the beats shown in Fig. 4, *VI* is variable and a comparison with Fig. 4, *I*, *II*, and *IV* shows that the new impulses are derived from areas which were previously active. Beats from three or more centres occur in haphazard sequence and follow each other at a rate of 232 per minute; no trace of auricular summits is to be found. It is probable that, with the establishment of the continuous tachycardia, the auricle is responding to ventricle and that the associated electric complexes approach the isoelectric state.

The Hürthle curve corresponding to this electrocardiogram is of peculiar interest, for it is, with the exception of the single long pause towards its termination, a regular and rapid pulse curve, in which the excursion of the several beats is approximately constant. Certainly the slight fluctuations seen are exaggerated when recorded by the mercury manometer, but the tracing as it appears in Fig. 3 might be readily mistaken, in the absence of other evidence, for that of a rapid and regular heart action of normal origin. The electrocardiogram, however, reveals the true nature of the condition; no single beat of sinus origin is present, but the mechanism is constituted by an ectopic rhythm generated in a number of ventricular foci. The importance of this conclusion is more evident when it is remembered that no *a priori* conclusions can be drawn in regard to the innervation of these new centres of impulse production. The approximate regularity of the tachycardia seems to be due to the appearance of a new contraction almost immediately at the cessation of the refractory period of the contraction which precedes it

Transitions between the simpler forms of irregularity shown in Fig. 4, *I-I V* and the tachycardia of Fig. 4, *V I* are common, and a single example which is taken from a separate experiment is shown in Fig. 5, the corresponding Hürthle curves as before being approximately regular. The auricular representatives are easily distinguished throughout the whole of this strip, but only a solitary normal cycle (*P*, *R* and *T*) is present. The premature contractions are coming from a number of separate ventricular foci.

A very curious type of tachycardia has been seen on several occasions and is illustrated by Fig. 6. It is a perfectly regular tachycardia generated from two separate ventricular foci, and the beats from one and the other focus occur alternately and follow each other at a rate of 312 per minute. In the corresponding Hürthle curves, the presence of two types of beat is recognisable only upon the very closest examination. The ventricular complexes of the beats follow each other so rapidly that each appears to start before the completion of the preceding one, and as a result the quick opening phases, some of which are directed upwards and some of which are directed downwards, do not start from the same abscissa. The explanation of the absence of return of the string to the isoelectric position before the occurrence of each new contraction is not apparent.

The effect of small doses of adrenalin upon the heart under the influence of low tensions of chloroform vapour.

In the first instance, it will be convenient to describe the result of injecting adrenalin, when the cat is under the full influence of chloroform ; the sequence of events is similar to that described in the following typical experiment. An animal was anæsthetised with chloroform of 2 per cent. strength, which was gradually reduced to 1·5 per cent.. Thirty-one minutes from the commencement of the experiment, the anæsthesia was well established at this percentage ; a faint corneal reflex was present, and the heart beat regularly at a rate of 160 per minute ; the mean blood pressure was low, namely, 63 mm. Hg.. Under these conditions, 0·065 milligrammes of adrenalin chloride were injected intravenously. Approximately twenty seconds after the injection irregularities commenced to show themselves in the electrocardiogram, the first premature beat being an accompaniment of the rise of blood pressure, which had at this point reached a height of 90 mm.. The premature ventricular contractions became more numerous as the pressure rose to 100 mm. and irregular mechanisms were encountered, which were similar to those previously described as occurring under the influence of light chloroform anæsthesia alone, (cp. Fig. 4, *V I*, and Fig. 5*). The

*The similar mechanisms described by Kahn[3] were obtained in dogs deeply anæsthetised by a mixture of chloroform and ether. (Communication by letter).

blood pressure having reached a maximum of 120 mm., the heart, 64 seconds from the time of injection, settled down into a regular tachycardia from a single point, probably located in the left or apical portions of the ventricular musculature. One minute later, the blood pressure had fallen to 105 mm., and the heart was beating at a regular rate of 210 per minute, and its mechanism was normal.

When the animal is under low percentages of chloroform vapour, the injection of adrenalin is followed by results which are far more profound than those obtained in animals under the higher percentages. It may be that, when the injection is administered, the heart is presenting the irregularities commonly found under light anæsthesia, or it may be that it is beating regularly ; but independently of its initial condition, and provided that the anæsthesia is light, the injection of 0·016 milligrammes or more of adrenalin chloride is followed by the appearance of multiple premature ventricular contractions, and finally the disorder of the mechanism culminates in fibrillation. This sequence of events is exemplified in the following description of the result of a second injection of adrenalin into the same animal, which was the subject of the experiment already recorded.

At the conclusion of the previous observation, the percentage was reduced to 0·5 per cent., and the injection of 0·065 milligrammes of adrenalin chloride was given fourteen minutes later. At the moment of injection the blood pressure was 130 mm. Hg., and the pulse rate 277 per minute, the mechanism of the heart beat being one of alternate beats generated in two separate ventricular foci, and the curves being similar to those shown in Fig. 6. This mechanism continued for seventeen seconds, and at the end of this time, the blood pressure measured 145 mm.. The mechanism of the heart then suddenly changed to one in which beats from a number of foci followed each other at a rate of 230 per minute, and this continued for a period of two seconds, the blood pressure rising abruptly at the same time to 180 mm.. At the conclusion of this period, the ventricles fibrillated.

In another instance in which the same quantity of adrenalin was injected under 0·5 per cent. chloroform, the heart at first beat quite regularly at a rate of 120 per minute, it then passed suddenly into a condition of irregular tachycardia, generated in multiple ventricular foci. This lasted for seventeen seconds and terminated in ventricular fibrillation. The latter part of the tachycardia and its passage into fibrillation is shown in Fig. 7.

As a rule the onset of ventricular fibrillation terminates the experiment, for the ventricles fail to recover from it ; but complete recovery from fibrillation lasting three seconds has been seen in one animal. From a number of kymograph tracings in our possession, it is obvious that permanent recovery from well established fibrillation is a rare event in the cat. In the above mentioned instance, a further injection under 0·5 per cent. vapour caused fibrillation, from which there was a temporary recovery, lasting some six seconds, the heart passing again into fibrillation, which, on this occasion, persisted.

When there is recovery from fibrillation, the mechanism at the offset is similar to that seen at the onset ; tachycardias of the several forms described are present. The normal sequence is re-established with the administration of higher percentages of chloroform.

Briefly, the irregularities produced by adrenalin in small doses, when the animal is under *high* percentages of chloroform, are of the same nature as the irregularities produced by low percentages of chloroform alone ; whilst small doses of adrenalin in the presence of low tensions of chloroform ultimately produce the highest grade of disorder, which is known to effect the ventricle, namely, fibrillation.

The electrocardiographic curve corresponding to ventricular fibrillation has been incidentally referred to by Kahn [2] and also by Jolly and Ritchie. [1] When the ventricle first passes into so-called fibrillation, its tone is increased, the visible movements are very active, and the oscillations are almost, but not quite, regular at a rate of 400 to 800 per minute. During this stage, a series of conspicuous and slow undulations usually occurs in the record, and this is well seen in Fig. 8. The curve as a whole shows a waxing and waning in the excursion of the oscillations at a rate of about 50-60 cycles per minute. The slow undulations are apparently associated with waves of tone change in the muscle, probably similar to the peristaltic waves spoken of by McWilliam.[7] This stage of fibrillation, from which recovery is evidently possible in the cat, gradually gives place to a second condition in which the ventricle becomes more distended and in which the slow undulations are absent or inconspicuous, and in which the rapid oscillations occur at a slower rate (300-360 per minute) and in a far more irregular fashion. This mechanism, from which recovery has not been observed, is shown in Fig. 9. Similar appearances were seen by one of us in a series of experiments upon obstruction of the coronary arteries, experiments which frequently terminate in ventricular fibrillation, and similar changes have been noted also where fibrillation has been induced by faradic stimulation. The change from one type of fibrillation curve to the other, therefore, is not confined to experiments under chloroform and adrenalin ; further, by whichever of these means fibrillation is induced, it is preceded by tachycardia of ventricular origin.

Discussion.

The hearts of cats, influenced by low tensions of chloroform vapour alone, or by adrenalin in the presence of high percentages of chloroform, exhibit disorders of mechanism of a very definite type. So far as our observations are concerned, the disturbances result purely from the production of new impulses in the ventricles. The nature of these impulses has been fully discussed by one of us in a recent publication, [6] and the beats have been termed *heterogenetic* on account of the short pauses which precede them and because they do not appear to stand as essential integers in a rhythmic

series of beats. Interpreting the events, in the light of the hypothesis put forward, we may state that the irregularities resulting from chloroform administration, are the outcome of an ever increasing tendency towards the production of heterogenetic beats ; at first isolated and generated from a single foci, these beats subsequently become more numerous, and arise from several foci ; eventually the rhythm of the ventricle is entirely dominated by impulses of this nature, and immediately prior to the onset of the final inco-ordination in the adrenalin experiments, a number of foci are active. Final fibrillation can only be regarded as a further step in the train of events ; it is believed that it results from the activity of a number of new foci of pathological or heterogenetic impulse formation, and that a grade of inco-ordination is produced in the ventricular musculature, such as precludes the output of blood from the organ and brings the circulation to a speedy standstill.

Chloroform in low percentages produces an enhanced irritability of the ventricle, a condition in which there is a widespread discharge of pathological impulses from the musculature, or a condition in which there is a tendency to such discharges. A further interference, such as is brought about by adrenalin injection, is followed by the highest grade of ventricular disorder, *i.e.* fibrillation, and death results. The method in which the adrenalin acts on hearts, whether, for instance, by directly affecting the heart muscle or indirectly through its pressor action, is not a matter which concerns the present investigation, and cannot be discussed here. It is apparent, however, from the foregoing considerations that the heart under low tensions of chloroform vapour may be in a condition which is the immediate antecedent of ventricular fibrillation. This is obviously a matter of important clinical interest in relation to the causation of sudden death under chloroform anæsthesia.

The experiments are also of interest in that they help to elucidate the pathology of ventricular fibrillation. They appear to confirm the supposition that this disorder of the musculature results from the generation of heterogenetic or pathological impulses from a number of foci in the chamber itself.

The tachycardias observed under low tension chloroform vapour are of importance ; they are of purely ventricular origin, and cannot be ascribed to any central nervous disturbance. They illustrate the value of the electrocardiographic method, for in the absence of records of this nature, the heart mechanism might be and probably has been mistaken for a normal or sequential one ; and the acceleration of heart rate might be readily ascribed to altered innervation. It is necessary to emphasise the danger of serious fallacy when conclusions are drawn from sudden accelerations or retardations of pulse rate as recorded by a mercurial or membrane manometer. Mechanical records of this kind fail to provide the experimenter with an analysis of the heart mechanism and the changes in rate are too often interpreted as the result of central nerve influences.

Conclusions.

1. Low tensions of chloroform vapour, administered to cats, produce high grades of irregularity of the heart. The irregularities are due to the production of new impulses in the ventricular musculature.

2. Small intravenous injections of adrenalin chloride produce, under high percentages of chloroform vapour, a condition of irritability in the ventricle, which is similar to that observed to result from low percentages of chloroform alone.

3. Low tensions of chloroform administered to cats together with small intravenous injections of adrenalin chloride ultimately produce the highest grade of ventricular disorder, *i.e.*, ventricular fibrillation.

4. Ventricular fibrillation is the result of the origin of impulses at a number of separate foci in the ventricular musculature.

5. The irregular and rapid heart beat referred to in the introduction of this paper as a common accompaniment of the administration of low percentages of chloroform, and as a precursor of isolated instances of death from ventricular fibrillation in cats, is in fact a transitional stage towards ventricular fibrillation.

BIBLIOGRAPHY.

1 Jolly and Ritchie. Heart, 1911, II, 177.

2 Kahn. Archiv f. d. ges. Physiol., 1909, CXXVI, 220.

3 Kahn. Archiv f. d. ges. Physiol., 1909, CXXIX, 379.

4 Levy. Proc. Physiol. Soc., 1911, XLII, iii.

5 Levy. Lancet, 1903, I, 1413.

6 Lewis. "Mechanism of the Heart Beat," London, 1911.

7 McWilliam. Journ. of Physiol., 1887, VIII, 296.

8 McWilliam. Journ. of Physiol., 1899, XXV, 4.

Fig. 4 × ⅔. A succession of electrocardiograms from a single animal; they are published as characteristic examples of the action of chloroform upon the cat's heart. The percentages of chloroform vapour are marked on the right hand corners of the respective figures.

I. A bigeminy resulting from the presence of premature ventricular contractions. The rhythmic beats are marked *P*, *R* and *T*, (*P*=auricle, *R* and *T*=ventricle). The premature contractions are complicated by the presence of the sequential *P*'s, which fall on the shoulders of the ascending portions of the corresponding ventricular complexes.

II. A trigeminy resulting from premature ventricular contractions of a different type. The electric curves corresponding to the premature contractions are complicated by the sequential auricular contractions (*P*), which fall in the centres of the corresponding complexes.

III. A bigeminy resulting from premature contractions, which are alternately of the forms shown in *I* and *II*. A simultaneous Hürthle curve is shown in Fig. 1.

IV. A trigeminy resulting from premature contractions of a third type. The sequential auricles are clearly shown upon the downstrokes of the electric complexes corresponding to the premature contractions.

V. The regular mechanism shown under 2 per cent. vapour. The rate of heart beats is 122 per minute. The corresponding Hürthle curve is shown in Fig. 2.

VI. A tachycardia produced by 0·5 per cent. vapour, and consisting of a complex mixture of beats of the types shown in *I*, *II* and *IV*. The tachycardia is due to the formation of impulses in several foci of the ventricular musculature. The corresponding Hürthle curve is shown in Fig. 3.

In all the curves, the upper line shows the signal, the second line fifths of seconds.

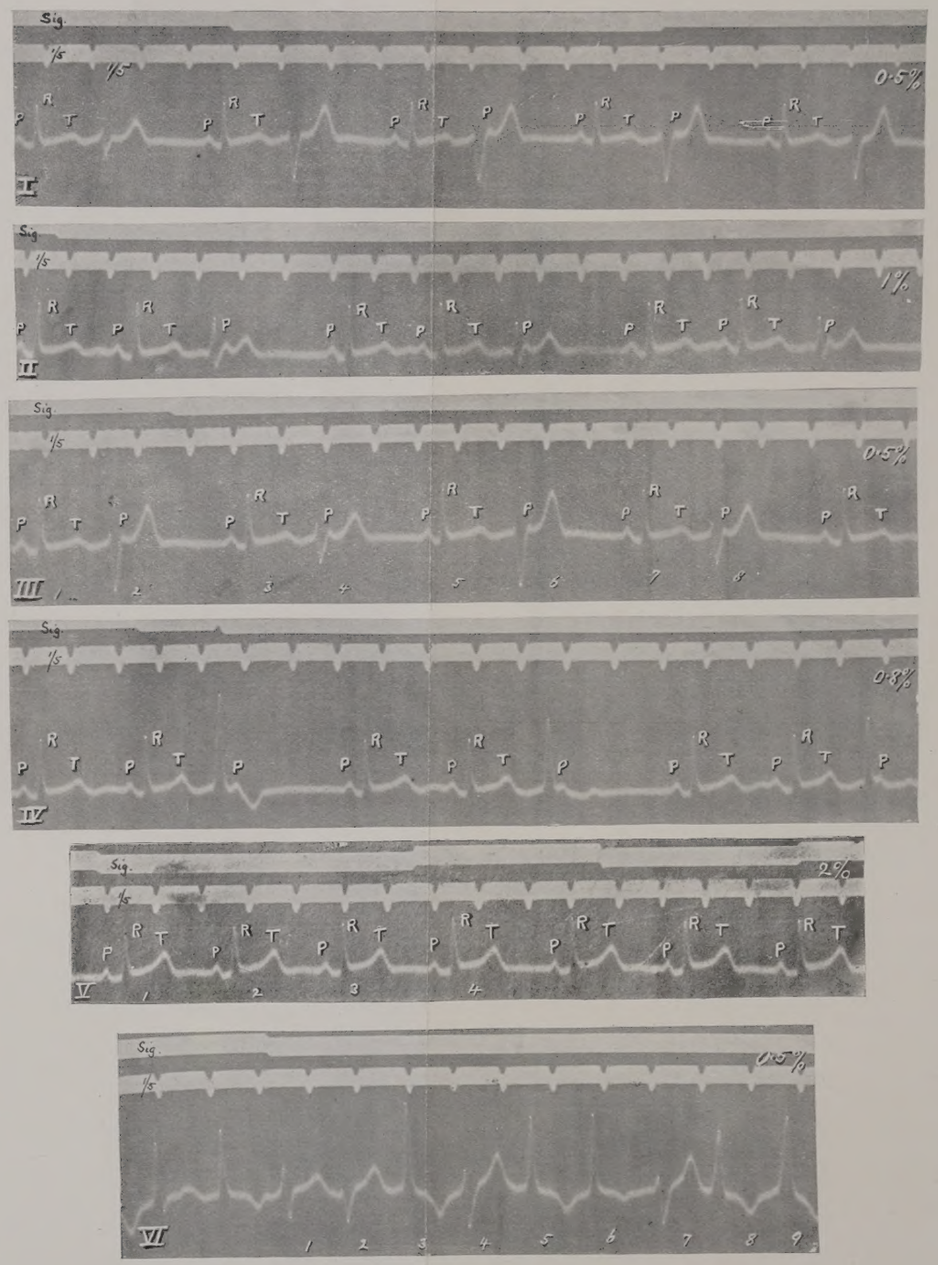

FIG. 4.

Fig. 5 × ⅔. An electrocardiogram from a cat under 0·5 per cent. vapour, showing marked irregularity resulting from premature ventricular contractions. Only a single normal or sequential beat is present; it is marked *P*, *R* and *T*, and lies in the centre of the figure. The rhythmic auricular contractions may be identified throughout the whole curve. They are marked *P*.

Fig. 6 × ⅔. Shows a tachycardia composed of premature contractions alternately generated in separate foci. This mechanism was present when the animal was upon 0·5 per cent. vapour

Fig. 7 × ⅔. The transition from a complex tachycardia to ventricular fibrillation The tachycardia was induced by the injection of adrenalin under 0·5 per cent chloroform, the heart being originally regular.

Fig. 8 and 9 × ⅔. Two electrocardiograms from a single animal; exemplifying the appearance of ventricular fibrillation, resulting from the injection of a small dose of adrenalin; shortly after its onset (Fig. 8) and a few minutes later (Fig. 9). In Fig. 8 the oscillations follow each other at a rate of approximately 780 per minute; a series of slow undulations is present in this curve; (it is at this stage that the heart is contracted and in very active movement). In Fig. 9 the oscillations occur at a much slower rate, approximately half the preceding rate, and the slow undulations are no longer present, (it is at this stage that the heart is markedly dilated, and that the movements consist of feeble flickerings on the surface).

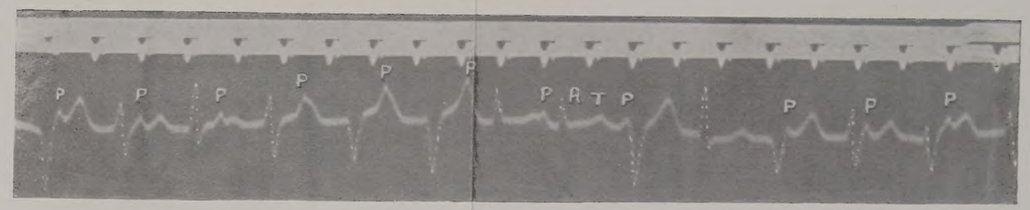

FIG. 5.

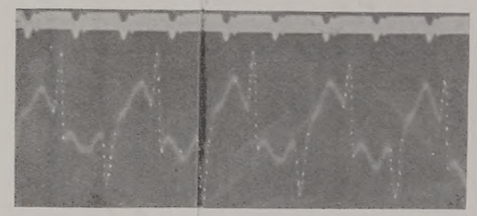

FIG. 6

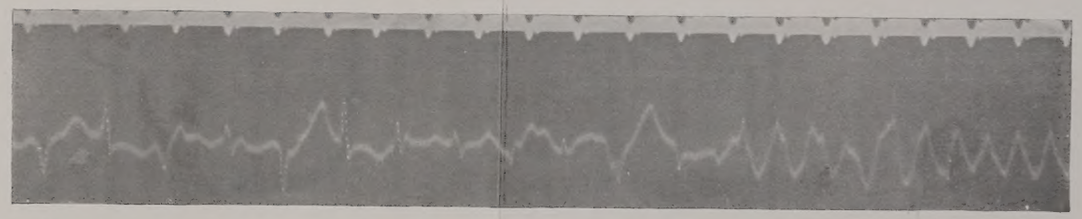

FIG. 7.

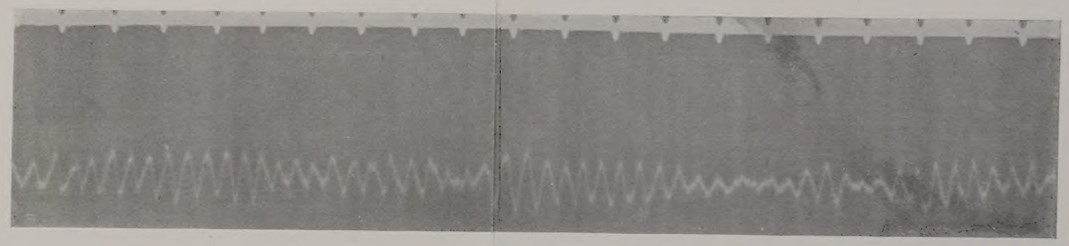

FIG. 8

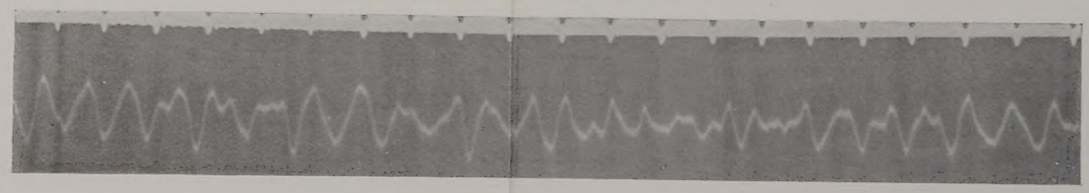

FIG. 9.

CONTENTS.

HEART-BLOCK FROM DRUGS OF THE DIGITALIS GROUP. THE COMPARATIVE EFFECTS OF DIGITALIS, STROPHANTHUS, SQUILL AND APOCYNUM 1

BY J. DAVENPORT WINDLE.
(*Southall.*)

PULSUS IRREGULARIS PERPETUUS WITH FIBROSIS OF THE SINUS NODE.. 13

BY G. DRAPER.
(*Rockefeller Institute, New York.*)

A CASE OF BRADYCARDIA WITH POST-MORTEM EXAMINATION .. 23

BY ALFRED E. COHN.
(*New York.*)

STUDIES ON THE CIRCULATION IN MAN.
I. THE MEASUREMENT OF THE BLOOD-FLOW IN THE HANDS 33
II. THE EFFECT OF REFLEX VASO-MOTOR EXCITATION ON THE BLOOD-FLOW IN THE HANDS 76

BY G. N. STEWART.
(*From the H. K. Cushing Laboratory of Experimental Medicine, Western Reserve University, Cleveland.*)

PAROXYSMAL TACHYCARDIA, ACCOMPANIED BY THE VENTRICULAR FORM OF VENOUS PULSE 89

BY H. HUME TURNBULL.
(*Melbourne.*)

HEART IRREGULARITIES, RESULTING FROM THE INHALATION OF LOW PERCENTAGES OF CHLOROFORM VAPOUR, AND THEIR RELATIONSHIP TO VENTRICULAR FIBRILLATION 99

BY A. GOODMAN LEVY AND THOMAS LEWIS.
(*From University College Hospital, Medical School.*)

A CASE OF COMPLETE TRANSPOSITION OF THE VISCERA, ASSOCIATED WITH MITRAL STENOSIS; INCLUDING A DESCRIPTION OF THE ELECTROCARDIOGRAPHIC TRACINGS 113

BY SYDNEY A. OWEN.
(*From the City of London Hospital.*)

VISCOSITY OF THE BLOOD 118

BY W. H. WELSH, M.D.
(*Edinburgh.*)